# Data-Driven Modeling of Target Human Behavior in Military Operations

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**ABSTRACT**: *This paper describes the Army-funded exploratory work in progress at the Target Behavioral Response Laboratory. The final objective of the project is to develop data-based general approaches to modeling and simulation of human behavior and quantitative methods of verification and validation. Crowd behavior data were collected under controlled laboratory conditions. Mathematical models of human behavior were derived which were then coded into computational models to produce predicted paths. These processes allow visual comparisons between outputs from simulations and behavioral data collected in the laboratory from human subjects. The results of these preliminary efforts will initiate further work in the methods of incorporating human behavioral data into models and validation procedures.*

## 1. Introduction

The current theaters of operation have sharpened focus on analytics relevant to irregular warfare (Department of Army Headquarters, 2009; National Research Council, 2011). A critical tool for operations research and systems analysts is the modeling and simulation of tactically relevant human behavior. Military modeling and simulation for the analyses of irregular warfare missions requires human behavioral data and models at the individual, organizational, and societal levels (Zacharias, MacMillan, & Van Hemel, 2008; National Academy of Sciences, 2008).

Challenges abound (Numrich & Tolk, 2010; Tolk, Davis, Huiskamp, Klein, Schaub, & Wall, 2010; Zacharias, MacMillan, & Van Hemel, 2008; National Research Council, 2011). Modeling and simulation experts recognize the complexity of human behavior and the typical methods for modeling of inanimate systems are not appropriate for the modeling of people. The typical approach is to select theories of human behavior thought to be relevant to the specific scenario and turn relationships among variables specified in the theory into code (Loftin, Petty, McKenzie, & Gaskins, 2005; McKenzie, et al., 2008; Moya, McKenzie, & Nguyen, 2008). There is a heavy reliance on social scientists as Subject Matter Experts (SME) for development and validation of models and resulting simulations (Goerger, 2003; Goerger, McGinnis, & Darken, 2005).

There are several specific criticisms of the current state of the art including lack of data on human behavior, incomplete and conflicting theories of human behavior, difficulty in turning theories of human behavior into code, architecture-specific models, reliance on Subject Matter Experts (SMEs) who cannot be expected to be unbiased in their evaluation, lack of objective methods for verification and validation of M&S products, and a lack of methods to validate against real world data.

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14. ABSTRACT
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Most critically, there is recognition of the lack of real-life data to provide guidance for these M&S efforts. Moreover, also lacking are methods to assess how well these M&S efforts relate to actual real life human behaviors (Zhou, et al 2010). One might propose that the lack of data on human behavior is caused by a lack of M&S researchers who are studying human behavior.

The Target Behavioral Response Laboratory (TBRL) is one such collection of scientists and engineers. TBRL's primary mission is to test the effectiveness of non-lethal weapons and systems, including crowd response to control force management with such weapons. In the past three years, the TBRL has collected behavioral, psychological, and sociometric crowd data on almost 350 individuals in 22 crowd events under varied equipment testing and experimental manipulations. (Cooke, Mezzacappa, & Yagrich, 2007; Mezzacappa et al, 2009a; Cooke et al, 2009; Mezzacappa et al 2009b; Mezzacappa, Cooke, & Yagrich, 2008; Cooke, et al, 2010; Reid, et al, 2011; Mezzacappa, et al, 2011).

Access to data on crowd-control force behavior has led the TBRL to develop a unique and innovative approach to M&S, where *data from behavior of real persons in tactically relevant scenarios* are the analytical link to the computational model. TBRL has received funding from an ARDEC In-house Laboratory Independent Research award to 1) develop and document methods and processes to generate computational models from mathematical models calculated from human behavioral data, and 2) to develop and document methods and processes to quantitatively verify and validate human behavioral models. The long-term goal of the study is to contribute to the creation of an M&S operational planning tool to provide commanders with the capability to predict crowd response to non-lethal weapon tactics, techniques, and procedures. A description of the initial results of the project follows.

## 2. Method

### 2.1 Data Recording Procedures

Participants were recruited from the general population to participate in an investigation on "Crowd Movement." Fifty-two men and women participated in one of seven experiment days. Subjects were healthy local residents or Picatinny Arsenal employees over the age of 18. Subjects targeted a protected area with simulated rocks for points/money. The area was protected with control force tactics utilizing foam projectiles, directed energy, and acoustic weapons in an attempt to cause the subjects to lose points/money (See Mezzacappa et al, 2011 for more information).

Subjects earned money for scoring points during the test and lost money for being hit by the control force during the test. Subjects also were paid $20.00/hr for participation. The single session experiment lasted 4-5 hours long.

During the experiment a computer recorded the subjects' location, orientation, and locomotion through the testbed. Specifically, motion capture cameras and video recording cameras (visual and audio) recorded the behavior of the members of the crowd during the entire experiment.

### 2.2 Modeling and Simulation Procedures

#### 2.2.1 Creation of the Mathematical Model from Subject Data

As an initial step, coders created mathematical models of human crowd behavior based on motion capture data collected for this purpose. Following from the TBRL research program, the primary behavior of interest was locomotion toward a target or goal (Figure 3.1). Motion capture methods were used to capture X,Y coordinate locations, and therefore the paths persons took toward the target.

The raw motion capture data were first processed using an input module created in MatLab. The primary results of this step are an output matrix of the subject data and a matrix of predictor variables. For these initial efforts, subject's current location and locomotion were the variables to be predicted from subject's initial and previous location. The results of this step were passed to a statistical model module. Based on the predictors (X,Y location), the module computed a best fit to a non-linear model predicting the velocity vector in both the X and Y components, thus generating model coefficients for change in location in X and Y coordinates based on empirical data.

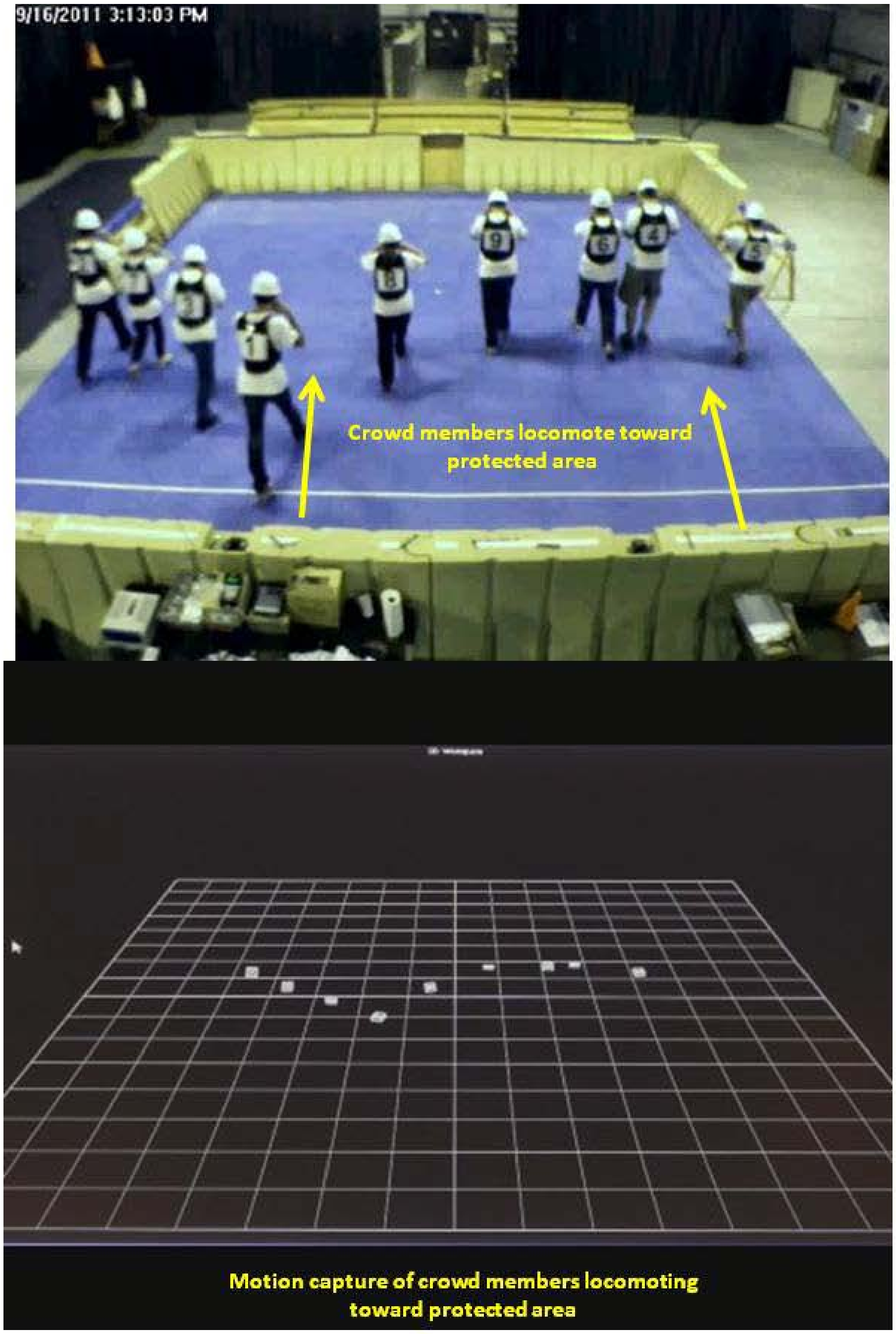


Figure 3.1

*Laboratory data capture of crowd locomotion toward a target area.*

### 2.2.2 Calculation of Agents' Predicted Paths

These resulting regression equations were then used as the computational model underlying a simple simulation algorithm to predict a simulated crowd member agent's change in location over time. The simulation module was a MatLab file that was built into an independent function that executed for each agent a time stepped simulation of a real subject's behavior, based on the provided model and start conditions. At each time step, the new locations were calculated and time advanced. The calculated current state was updated and appended to the resulting file. Then the function stepped through each iteration calculating the change in X and Y directions, the change in distance, and the change in position for each agent.

### 2.2.3 Comparison of Subject Data and Agent Paths

The display module was a MatLab file that was built into an independent function that displayed the time plots of the real subjects' data and predicted agent paths. That is, the function created plots of the raw captured data and the simulated movement pattern for each agent crowd member, allowing for a side-by-side view of movement patterns. The function scaled the plots appropriately so that both plots had the same axis limits.

## 3. Results

A graphical visual comparison can be made between the mathematical representations or parsing of the behaviors as they are modeled in the computer and the data recorded in laboratory (Figure 3.2). To our knowledge, this is the first instance where output from a simulation of human behavior has been directly compared with data collected from actual human behavior.

Initial attempts fell short (Figure 3.2). Subsequent models proved to be closer in reflecting the actual data in the laboratory (Figure 3.3).

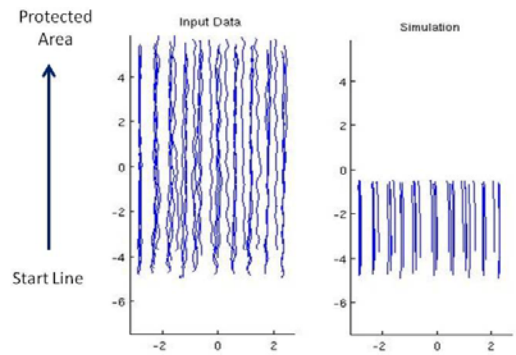


Figure 3.2

*Comparisons between behavioral data recorded from humans under controlled laboratory conditions (left) and output predictions from computer simulations, initial model (right).*

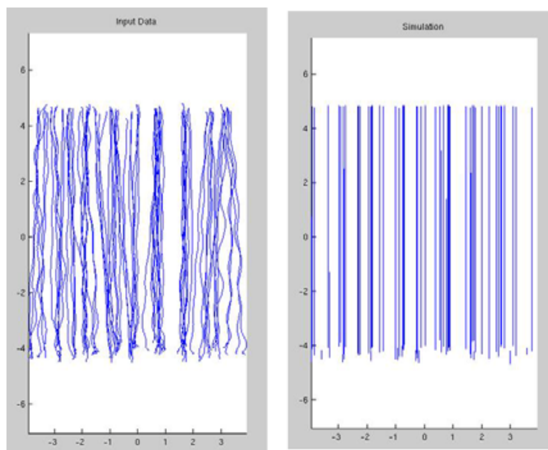


Figure 3.3

*Comparisons between behavioral data recorded from humans under controlled laboratory conditions (left) and output predictions from computer simulations, subsequent model (right).*

More complex models incorporating the actions of a control force protecting a goal were then created (Figure 3.4). Again, paths were recorded and mathematical models were derived to predict paths toward goals (Figure 3.5). While these simulated data were able to capture the central tendency of the data, the variability

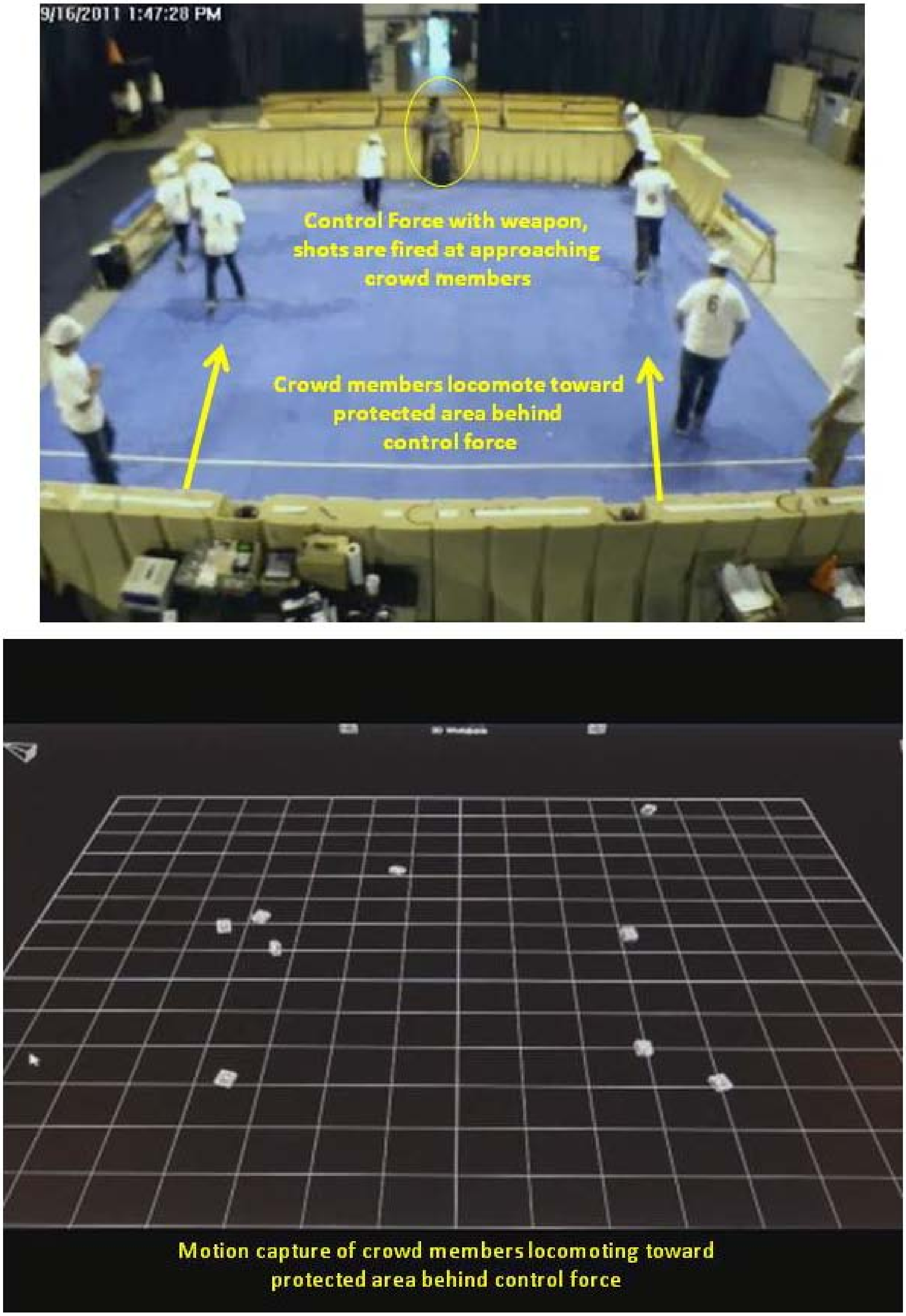


Figure 3.4

*Laboratory data capture of crowd locomotion toward a target area protected by control force.*

among the paths was not reflected in the data outputted from the simulation. Understanding that this was a shortcoming of the mathematical model, random error was introduced into the model, resulting in a graphic more closely resembling the recorded paths of the laboratory subjects (Figure 3.6).

## 4. Discussion

The preliminary results indicate that theTBRL was successful in developing an overall process for collecting data from real people, creating simple mathematical and computational models of crowd member movement, and generating output that is directly comparable to the initial data collected in the laboratory.

Although we have succeeded in the primary goals of getting from data to model to comparisons between human data and model output, the model needs refinement. Specifically, we would like to continue model development to account for individual differences among crowd members, collective level differences among different crowds, as well as account for other factors not yet identified included in the model, including possibly important psychosocial or demographic variables.

Moreover, there exist other approaches to modeling of human behavior, such as neural network perspectives. Finally, the issue of incorporation of natural data variability will also be explored. The intent is to utilize the results of the prior work to create, evaluate, and identify mathematical models that will yield more accurate computational models; and simulations whose outputs will more accurately predict both the actual behavior of humans recorded in the laboratory and as well as the actual behavior of humans in theaters of operation.

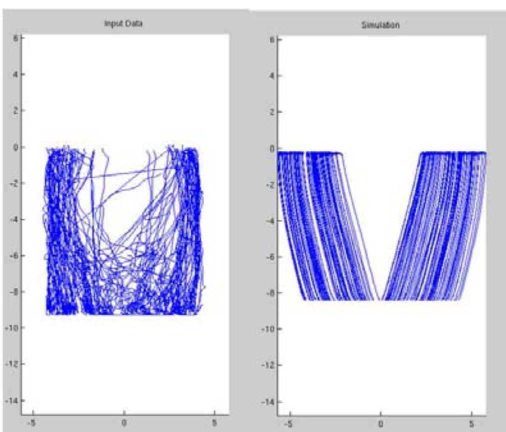


Figure 3.5

*Comparisons between behavioral data recorded from crowd control force encounter (left) and output predictions from initial simple computational models (right).*

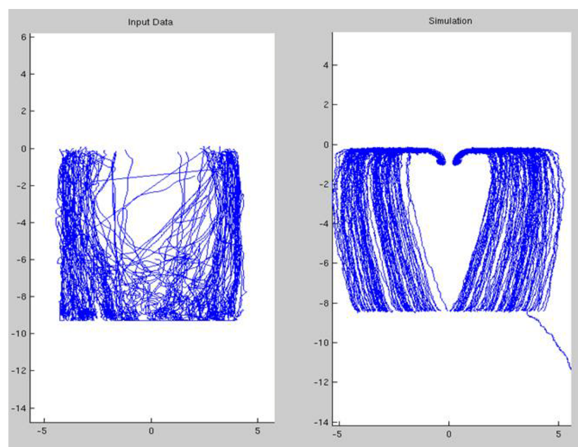


Figure 3.6

*Comparisons between behavioral data recorded from crowd control force encounter (left) and output predictions from computation model incorporating random error components (right).*

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